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environment

MOE Working Report

Summary Information Package on Acid Rain Effects on Forests and Lakes of British Columbia

BC
MINISTRY OF
ENVIRONMENT

Province of British Columbia
Ministry of Environment

MOE WORKING REPORT

SUMMARY INFORMATION PACKAGE

ON

ACID RAIN EFFECTS

ON

FORESTS AND LAKES

OF

BRITISH COLUMBIA

AIR MANAGEMENT BRANCH

VICTORIA, BRITISH COLUMBIA

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HOW TO USE THIS INFORMATION PACKAGE

This package has been designed to present concisely: Ministry Position, supporting Discussion, point form statement of Acid Rain Effects on lakes and forests, and some further explanation of these effects. The presentation format provides a maximum of information in a minimum of text. The appended tables and maps provide data support for the statements in the text.

Acid Rain and Forest Health

This section provides a formal statement of the position of the Ministries of Forests and Environment.

Discussion

This section provides the reader with some insight in the factual considerations which led to the Ministry Statement.

Acid Rain Effects

This table lists the most common effects that acid rain may have on the environment. Since we have not, as yet, recognized acid rain damage in British Columbia, this list is theoretical. The listed effects may occur in British Columbia in the future.

Notes to the Acid Rain Effects

The points listed in the previous table are further explained in these notes.

Useful Literature

The listed reports were the source for much of the information included in this Summary Package. If your curiosity has been piqued, you can obtain

copies of these from the Ministry of Environment (as and when available).

Appendices

The appendices present, in graphic or tabular form, the information referenced in the text. The appendices will be helpful in providing precise data and showing relationships to other information.

It is suggested that the reader use the Ministry positions in ACID RAIN AND FOREST HEALTH precisely as stated. It may be useful to provide the inquiring public with a copy of this page. All other information is intended to provide government personnel with sufficient background to explain the Ministry position and to respond to further discussion with relevant facts.

ACID RAIN AND FOREST HEALTH

At present damage to forests and lakes attributable to regional acid rain has not been detected in British Columbia. (Local point-source related air pollution damage cases are addressed through the usual permitting and regulatory processes, and are not commonly considered a part of the Long-Range Transported Air Pollutants responsible for regional and global acid rain). Sulphate deposition with rain along the Pacific coast is generally between 5 and 8 kg/ha per year. A notable exception is the deposition estimated between 26.1 and 34.4 kg/ha in 1987 and 23.1 kg/ha in 1988 in Squamish just north of Greater Vancouver. Acidity of rain typically ranges between pH= 4.6 and 5.0. Extremes of pH= 3.8 have been noted in the Squamish area. Typical sulphate loading is less than that suggested as damage thresholds of the most sensitive lakes (9 kg/ha in Sweden, 11 kg/ha in Minnesota, and 12 kg/ha for British Columbia. See Appendix 1). It is well below the Canadian Objective of 20 kg/ha per year, which is designed to protect "all but the most sensitive lakes". However acid deposition in the area north of Vancouver is exceeding these thresholds significantly, thus raising concern for acid rain impacts. Although under the urban influence possibly slight reductions of lake pH have been noted, impacts on aquatic biota and the forests have not been observed. Rain acidity at pH= 3.8 is well above pH 2.7 (a generalized thresfhold pH of 3.0) is often reported) which can cause chemical corrosion of the protective surfaces (cuticles) of the plants.

DISCUSSION

Sulphate and other acidic compounds occur even in a pristine environment. Studies have shown that sulphates is a major component of acid deposition and that "Sulphates" is a good indicator of man-made acid deposition. Atmospheric concentrations under pristine conditions are referred to as "background levels". Typical background concentrations of sulphate in the air are less than 2 parts per billion. Background sulphate deposition rates are about 3 to 6 kg/ha per year. The background pH of rain varies with the nature of the geologyof an area (natural dust) from approximately pH= 5,0 in an acidic environment to as high as pH=6.0 in arid areas. A theoretical value of pH= 5.6 reflects only the effects of CO_2 on "clean water".

Information on acid content of rain exists for a limited number of locations (see Appendix 2) which were selected to reflect specific situations such as areas expected to experience regionally-elevated acid loading, localized source-linked instances of acid loading, or areas reflecting the typical background of acid content of the rain. A high estimate of acid deposition for British Columbia was between 26.1 and 34.4 kg/ha per year for the Squamish and Seymour Dam areas just north of Greater Vancouver under influence of significant industrial development and urban emissions (Appendix 3). This deposition value exceeds the threshold for initial effects on sensitive (poorly buffered) waterbodies. As many of our coastal waterbodies have been rated "sensitive to acidification " (see Appendix 4) concern about acid rain has been raised. A slight decrease in pH has been noted for three lakes near Vancouver: Capilano Lake, Coquitlam Lake, and Seymour Lake. The cause for this decline

is as yet unknown. The pH of these lakes remains above 6 and adverse effects on the aquatic flora and fauna are not anticipated (see Appendix 5). Ten (10) out of 752 lakes that were measured for pH were found to have pH< 6.0 (see Appendix 6). The causes for these low pH values may be natural or man-made.

Vegetation generally is substantially more tolerant to acid rain than lakes and streams. The sensitivity of our unique British Columbia species and terrestrial ecosystems is largely unknown and it is not feasible to project a "forest decline threshold". Therefore the health of the forest is continually monitored by Forestry Canada in a few critical locations (ARNEWS) throughout British Columbia (see Appendix 7).

A special case of "acid rain" effects may occur at the base of clouds where acidity may concentrate to levels that may cause corrosion of the leaf surfaces. Furthermore, in this belt oxidants and peroxides may concentrate to act incombination on the forest species. Information on some of the acid rain chemistry is being collected on Mount Seymour by the Ministry of Environment. Some symptoms resembling possible cloud-base oxidant injury have been observed on Burnaby Mountain. Such symptoms have not been reported for anywhere else in British Columbia.

Ground level ozone injury may have been observed in several locations near Greater Vancouver. It is not known if such injury events occur frequently enough to cause long-term decline in forest growth. However no tree deaths have thus far been attributed to this cause. Effects of ozone on tree growth are, at present, being investigated cooperatively by the Ministries of Forests and Environment, the Greater Vancouver Regional District, and Washington State and Simon Fraser Universities.

ACID RAIN EFFECTS

The term "Acid Rain" refers to a complex of environmental factors. Among the potential effects from acid rain are:

A. <u>On Lakes and Streams</u>

1. Reduced bi-carbonate (HCO_3^-) availability for photosynthesis for aquatic plants, changing the littoral vegetation;
2. Changes and/or reduction in algal, mollusc, and insect communities, thus changing foodwebs for higher organisms such as amphibians, fish, aquatic mammals, and waterfowl;
3. Increased aluminium levels toxic for fish and amphibians;
4. Increased heavy metals toxic to man and animals;
5. Reduced reproductive success for fish and waterfowl;
6. Altered metabolism causing deformities in aquatic fauna.

B. <u>On Forests</u>

1. Chemical corrosion of surface tissues of plants by strong acidity;
2. Soil nutrient leaching and soil acidification;
3. Toxic metal mobilization at greater acidity;
4. Inhibition of mycorrhiza and humus-decomposing micro-organisms by low pH and accummulations of toxic compounds;
5. Tissue-nutrient leaching following membrane damage by oxidants;
6. Delayed freeze-hardiness from atmospheric nitrates.

NOTES TO THE ACID RAIN EFFECTS

A. On Lakes and Streams

1 Reduced HCO_3^- availability for photosynthesis - CO_2 is taken up in water in part in the form of HCO_3^- at a pH range 5 to 10. From pH = 6.0 downwards, the proportion of HCO_3 declines steeply to be negligible below pH = 5.0. Some aquatic plants which are adapted to utilize bicarbonate for photosynthesis will be eliminated.

2 Changes and/or reductions in algal, mollusc, and insect communities, thus changing foodwebs - many organisms have been demonstrated to be pH dependent. A reduction in base metals (Ca, Mg) and a lower availability of nutrients prohibit the continued survival of these species. Species preying on the former will also be eliminated.

3 Aluminum Toxicity -
At lower pH, aluminum concentrations in water may increase to levels toxic to fish and amphibians. The dissolved aluminum may coat the gills and cause gradual suffocation.

4 Heavy Metal Toxicity -
At lower pH, many heavy metals including cadmium, manganese, and mercury are more soluble in water. Higher concentrations may be toxic to the organisms. Accumulations in fish may render the fish not suited for human consumption.

5 Reduced Reproductive Success -
Reduced reproductive success is attributed to the lack of calcium at pH <5.5 which affects

egg production, hatching success, and survival of juveniles. Some evidence of adverse effects on waterfowl reproduction has been found.

6 Altered Metabolism -
Low pH may lead to improper metabolism of body salt, calcium, and other elements causing skeletal deformation.

B. On Forests

1 Acid Damage to the Protective Skin (Cuticle) -
pH of less than (3.0) 2.7 is required to corrode the waxy cuticles of plants. Such extreme pH values, if found at all, may occur at the base of clouds.

2 Nutrient Leaching from the Soil -
With the exception of coarse-textured, infertile soils, this has not been found to be a significant risk in British Columbia. In high rainfall areas, soil acidification and nutrient leaching is a natural process. In these areas, ecosystems have evolved a greater dependence on nutrient cycling through the humus of the forest floor. Mis-management of this humus layer may, therefore, have serious consequences.

3 Toxic Metal Mobilization -
At soil pH <4.7, certain metals - particularly aluminum - may become soluble in the soil solution. These metals are toxic to plant roots by inhibiting fine-root growth. This may cause poorly developed root systems. As a result, the plants are less able to scavenge soil moisture and thus, succumb to drougt earlier. In British Columbia, soil pH <4.7 is typical for many soils. In these soils, special adaptations have evolved. Many forest species spread their feeder roots immediately

below the humus layer thus, avoiding the toxic metal sources. Also, the toxic metals may become attached to organic matter and thus, be neutralized.

4 Acid Rain Toxicity for Soil Micro-organisms - Unfavorable pH for the micro-organisms that cause the release of nutrients from the humus, an unbalancing of the relative proportions of nutrients, and an accumulation of toxic "heavy metals" (lead, mercury, copper, zinc, cadmium, etc.) are among the factors that may inhibit the proper functioning of the micro-organisms and fungi in the forest floor. Poor nutrient availability and uptake , and poor water uptake by plant roots may result.

5 Oxidant (ozone, PAN, peroxides) Damage to Membranes and Tissue-Nutrient Leaching - Ozone at lower altitudes, and peroxides and ozone at the base of the clouds may react with the unsaturated chemical bonds in the cell membranes thus, causing "leaks". Acid rain, being a somewhat better solvent (like a few drops of vinegar in water for stain removal) may then leach essential nutrients from the leaves and stem tissues at a rate greater than that at which the plants replenish these nutrients through the normal sap stream from the roots. Nutrient deficiencies are created in these tissues, and the typical deficiency symptoms may become visible.

6 Winter-hardiness Reduction - Hardening off is triggered by a reduced supply of nitrogen from the senescing foliage. A continual supply of nitrogen from nitrates in the atmosphere may counter the first reduction of nitrogen supplies to the roots and thus,

delay the onset of winter hardiness. This may make plants susceptible to damage from early incidence of freezing.

USEFUL LITERATURE

For further detail on the preceding information, the following literature may be consulted:

Acid Rain in British Columbia. April 1988. Ministry of Environment and Parks.

Annual Report 1986. Western and Northern Canada Acid Deposition/LRTAP Activities. British Columbia Ministry of Environment and Parks.

Annual Report 1987. Western and Northern Canada Acid Deposition/LRTAP Activities, British Columbia Ministry of Environment and Parks.

Canadian Forestry Service, 1986 unpublished. Summary sheet of ARNEWS plot locations and characteristics. Pacific Forestry Centre, Victoria, British Columbia.

NAPAP 1987. Interim Assessment of the Causes and Effects of Acidic Deposition. Vol 1: Executive Summary. National Acid Precipitation Assessment Program, Washington, DC 20503.

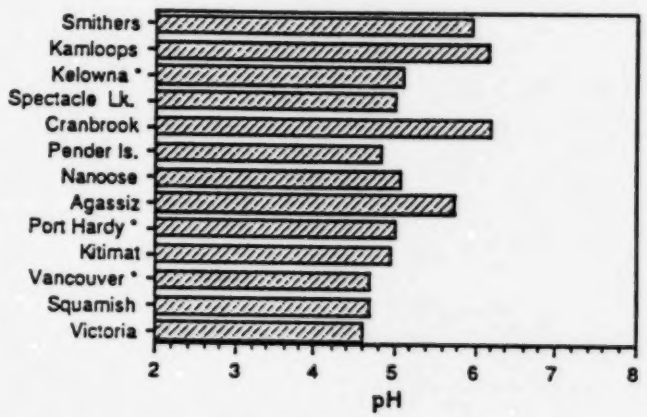
Interim Target Loadings for Acidic Deposition in Western Canada: A Synthesis of Existing Information. Western and Northern Canada.

LRTAP Technical Committee, March 1987. British Columbia Ministry of Environment and Parks, Victoria, British Columbia.

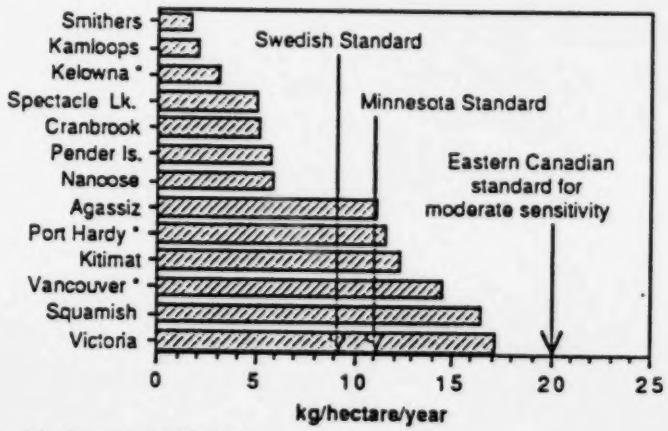
Ministry of Environment and Parks, 1987. Second Report on Chemical Sensitivity of British Columbia Lakes to Acidic Inputs.

Appendix 1

Acidity of Precipitation in British Columbia



Sulphate Deposition Levels in British Columbia

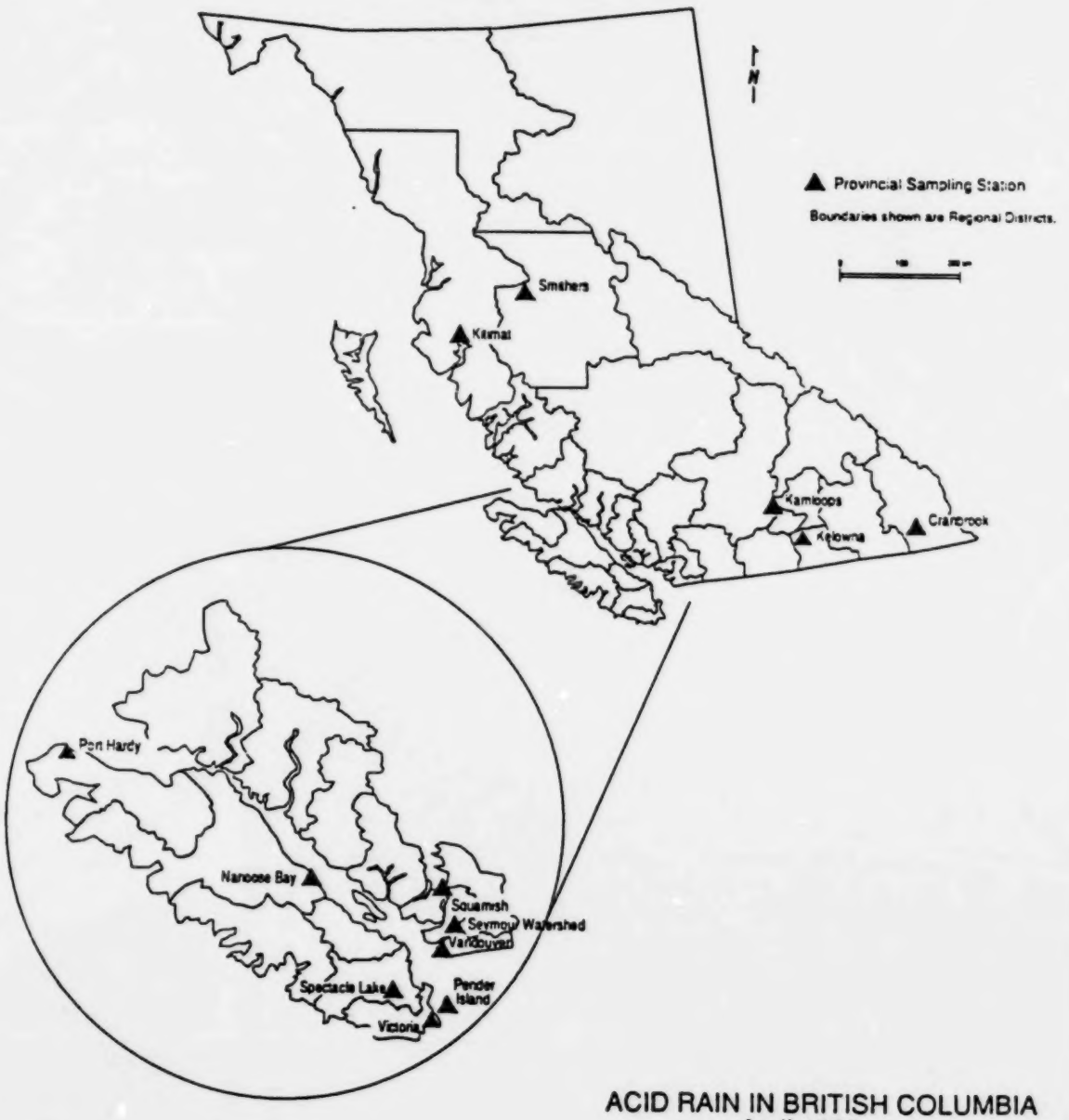


Note: * indicates 1985 data

ACID RAIN IN BRITISH COLUMBIA
April 1988

Appendix 2

Precipitation Chemistry Stations in British Columbia



ACID RAIN IN BRITISH COLUMBIA
April 1988

Appendix 3

Annual Deposition of Wet Sulphate at Sampling Stations in British Columbia.

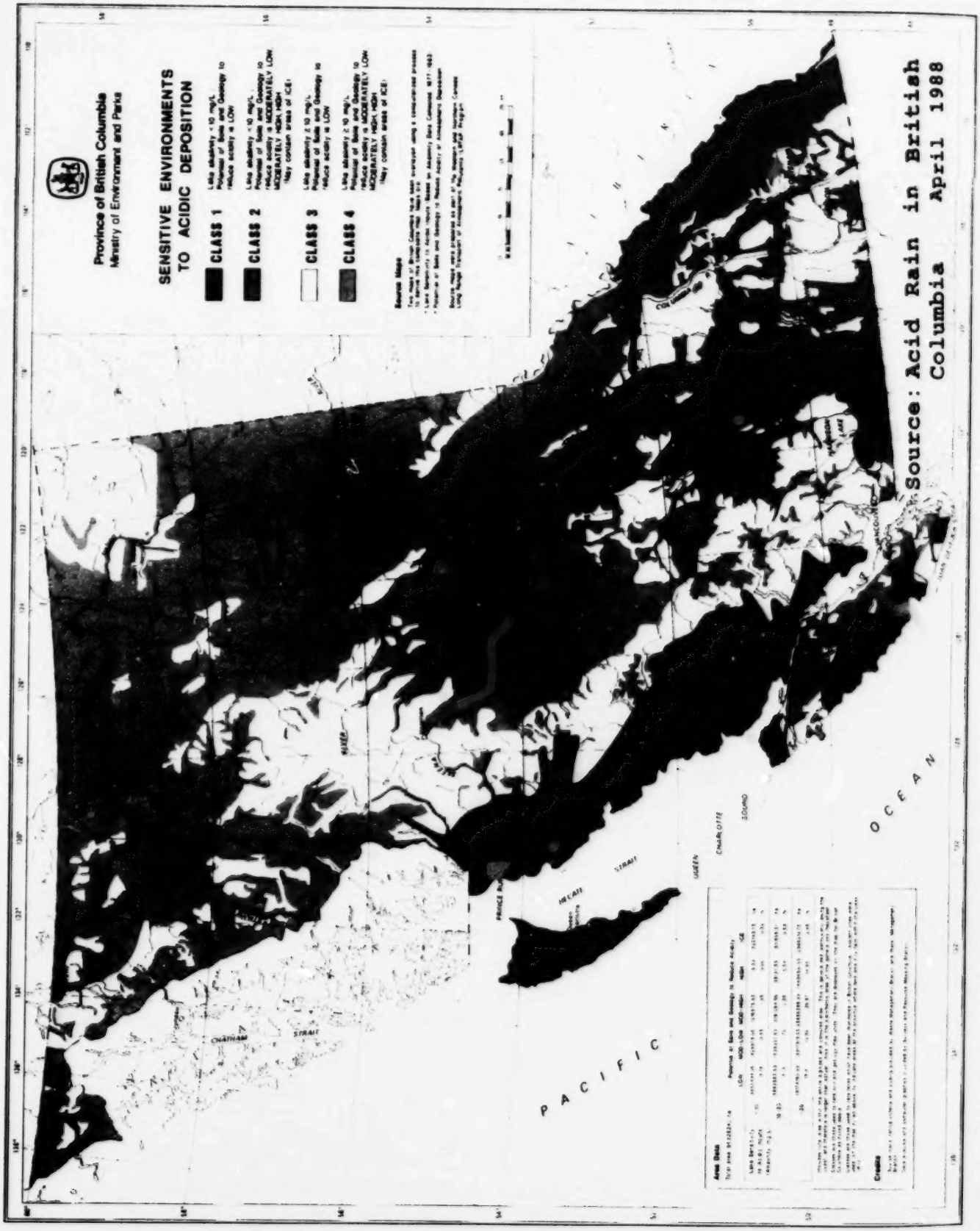
STATION	Annual Deposition of Wet Sulphate (SO_4^-) kilograms per hectare.						
YEAR	1982	1983	1984	1985	1986	1987	1988
Agassiz	-	-	-	11.4 (10.4)	12.5 (11.2)	-	-
Cranbrook	-	-	-	-	5.9	4.8	6.7
Dawson Creek	-	-	-	-	-	-	-
Fort Nelson(1)	6.3	4.4	5.0	4.0	-	-	-
Ft St John (1)	6.0	6.0	5.8	4.4	-	-	-
Kamloops	-	-	-	-	2.0	1.5	1.7
Kelowna (1)	3.4	3.0	-	3.1	- 13.7	1.7	2.0
Kitimat	-	-	12.0	-	(12.4)	16.9 (22.1)	13.4
Nanoose	-	-	-	7.9 (6.2)	7.4 (5.9)	7.2	6.3
Pender Island	-	-	-	5.8 (4.4)	7.1 (5.7)		6.4
Port Hardy(1)	15.1 (8.0)	15.8 (9.5)	19.4 (14.3)	-	-	13.1	14.7
Prince George(1)	16.4	8.7	5.7	7.9	-		
Revelstoke (1)	6.1	5.8	6.1	4.4	-		
Sechelt	-	-	-	7.9	8.0e		
Seymour Dam	-	-	-	-	-	32.4	30.5
Smithers	-	-	2.3	-	1.7	2.0	2.3
Spectacle Lake	-	-	-	4.7	4.9	12.3	4.0

STATION	Annual Deposition of Wet Sulphate (SO_4^-) kilograms per hectare (continued)						
YEAR	1982	1983	1984	1985	1986	1987	1988
Squamish	-	-	-	17.7	18.7	26.1 (34.4)	23.1
Terrace (1)	4.5	4.4	8.3	10.1	-		
Vancouver (1)	22..2 (19.9)	22.4 (20.4)	-	16.4 (14.9)	-	12.8	14.9
Victoria	-	-	18.7	10.9 (8.4)	20.3 (17.1)	17 7	19.6

Note: These values are estimated on the basis of available information on annual precipitation and chemistry of collected precipitation. The error inherent in the estimates may vary substantially depending on the availability of data. Kotturi suggests an acceptable error of ± 20%. For details the reader is referred back to the original publications:

Sources: Western and Northern Canada Acid Deposition/ LRTAP Activities.
Annual Report 1986 - April 1987
Annual Report 1988 - August 1988
M.Kotturi,unpublished report.1988 estimates

Parentheses enclose alternate estimates.

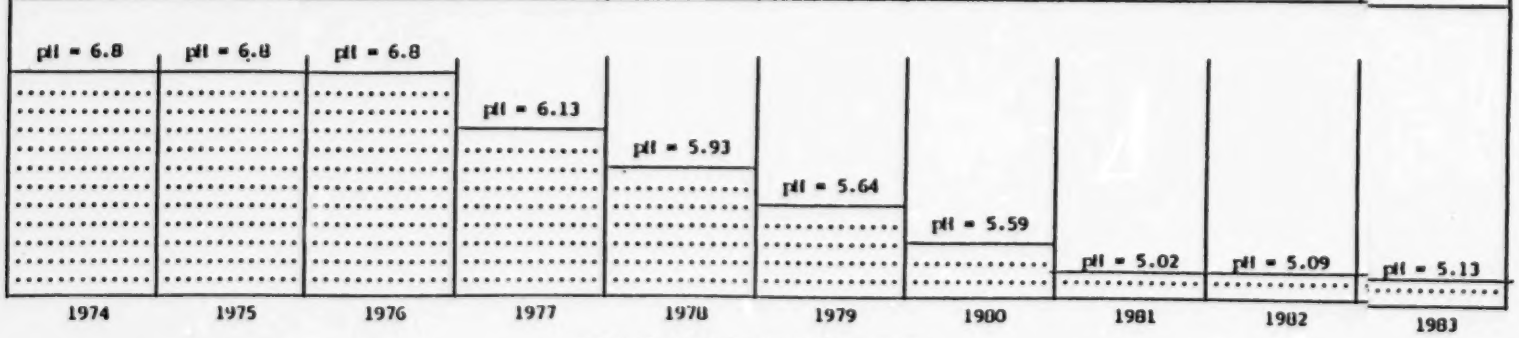


Source: Acid Rain in British Columbia April 1988

Appendix 5

Summary of results of experimental acidification of Lake 223 in northwestern Ontario. (Source: Schindler, D.W. et al. 1985)

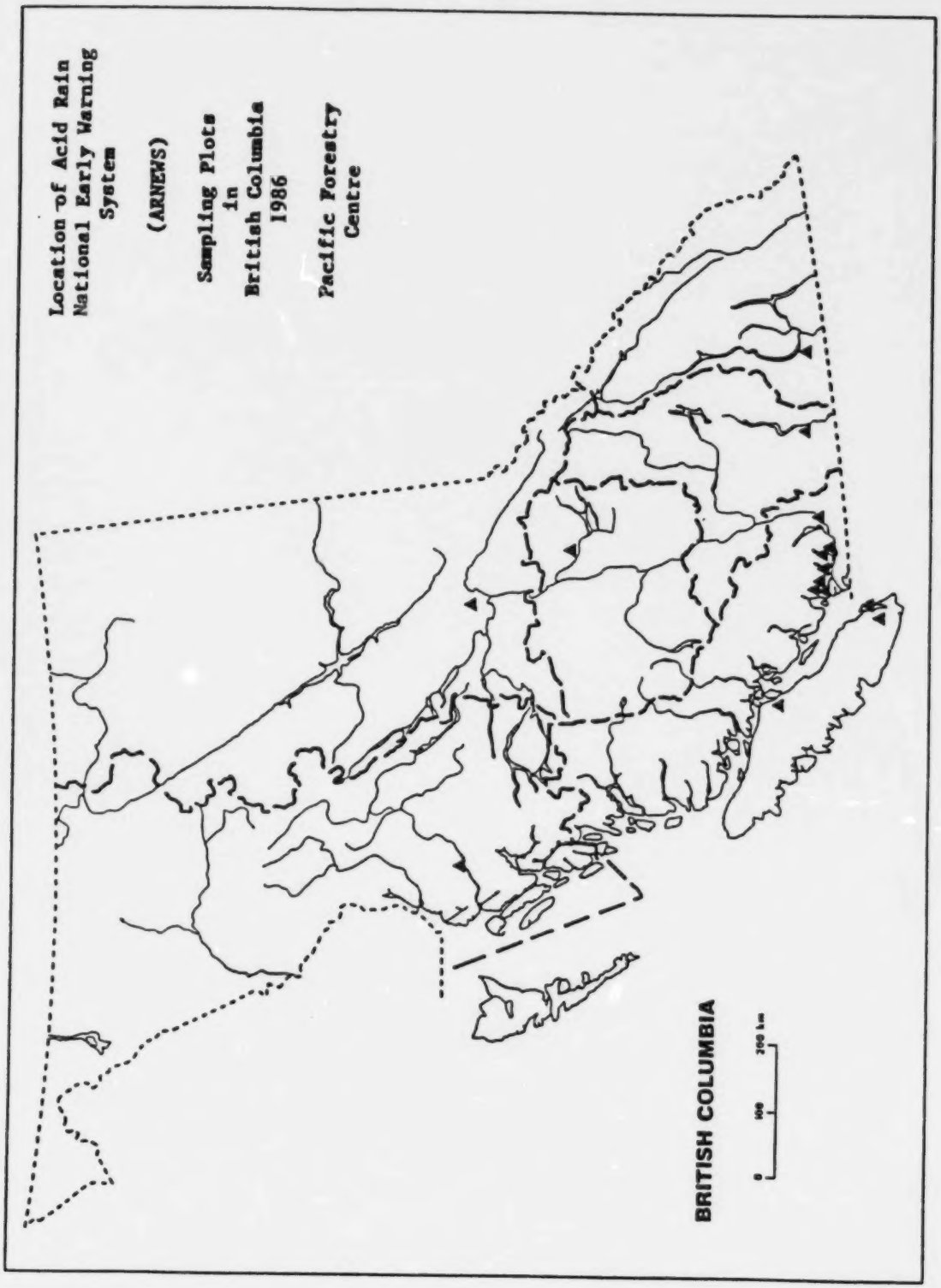
PHYTOPLANKTON					changes in species abundance	alterations continue; larger spp. increase	species mix stabilizes	
ZOOPLANKTON					changes in species abundance	alterations continue	alterations continue; smaller spp. increase	species mix stabilizes	
ALGAE					thick mats form along shoreline (mougeotia)			algal mats interfere with lake trout spawning	
INVERTEBRATES				freshwater shrimp disappear; flies increase	crayfish fail to harden shell	flies prosper; crayfish diseased; fail to reproduce			
FORAGE FISH				minnows fail to reproduce	minnows extinct	dace, suckers prosper, minnows extract, sculpins decline	dace, sucker recruitment fails; sculpins rare	no recruitment in any species	no recruitment by any species
LAKE TROUT		physical condition improves			physical condition improves	physical condition back to normal; no recruitment	no recruitment	physical condition very poor; no recruitment	physical condition worsens; cannibalism increases



Acidification Regime 1974 - 1983

MASON
pH-5.5
KALUM POND
pH-5.7
RAINBOW
pH-5.5
MAYER
pH-5.0
(Lots of fish)
BATCHELLOR
pH-5.9
GAMBLE
pH-5.8
LONG
pH-5.9
HAGGEN #1: No suitable habitat
pH-5.9
UBC #1
pH-5.8
KENYON
pH-5.3
SECOND REPORT ON CHEMICAL SENSITIVITY
OF B. C. LAKES TO ACIDIC INPUTS
MINISTRY OF ENVIRONMENT AND PARKS
PROVINCE OF BRITISH COLUMBIA
SEPTEMBER 1987
Lakes With pH< 6.0

Appendix 7


Location of Acid Rain
National Early Warning
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(ARNEWS)
Sampling Plots
in
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1986
Pacific Forestry
Centre
BRITISH COLUMBIA
0
500
250 km